Recovery of energy and manure from solid wastes: A study on the solid waste management of Kottayam town

1. Introduction

Solid wastes are all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted. It encompasses the heterogeneous mass of throwaways from residence and commercial activities as well as the more homogeneous accumulations of a single industrial activity (Peavy *et al.,* 1985). Municipal Solid Waste (MSW) is defined to include refuse from the households, non-hazardous solid waste discarded by the industrial, commercial and institutional establishments, market waste, yard waste and street sweepings which are collected by the municipal authorities for disposal (Jain, 2007).

Waste Management is now a problem not only of urban areas but also in semi-urban and rural areas. Waste takes up space and does not disappear by itself. Waste lying on roadsides, low lying areas and vacant places, outside drainages etc. not only mars the aesthetic beauty of that place but is a serious health and environmental hazard to the people. Animal feeding on this waste and consuming all polythene and hazardous waste mixed with kitchen waste is a serious health hazard to them. Open burning of household wastes release toxic compounds like carbonyls, volatile organic compounds, poly aromatic carbonyls, dioxin, vinylchloride, CO, CO_2, SOx, NOx, hydrocarbons etc. causing serious health impacts. Shallow open dumping of solid waste implicated very strongly with emissions of CH_4 and CO_2 –where methane is a green house gas (GHG) more harmful than CO_2. Unscientific methods adopted for the disposal of solid wastes is therefore a serious health concern. The inadequately maintained MSW disposal sites (landfills) are prone to pollute ground water, spread disease vectors, mosquitoes, rats and other pests.

Kottayam municipality is located in the south central part of Kerala. It has more than fifteen thousand families as residents and a host of business and office/bank establishments and educational institutions. Over the past two decades, urbanization of Kottayam has resulted in to an increased rate of waste generation causing severe threat to the environment and public health. The

present MSW dumping yard is located near Vadavathoor in Vijayapuram Grama Panchayat of Kottayam district. The site is about 4 km away from Kottayam town on the north-western side of Kottayam-Kumali Road. Jacob (1999) estimated the generation of waste in Kottayam municipality as 15.5 tons per day. The unsorted waste reaching in the dumpyard is the major issue causing difficulties in the proper management / selection of scientific technologies to process and dispose the waste. Various kinds of environmental problems have also been identified associated with the dump yard due to its improper management practices.

Waste-To-Energy (WTE) processes recover energy from the waste through either direct combustion (e.g., incineration, pyrolysis, and gasification) or production of combustible fuels in the forms of methane, hydrogen, and other synthetic fuels (e.g., anaerobic digestion, mechanical biological treatment, and refuse-derived fuel). WTE is gaining popularity throughout the world primarily for its ability to reduce the volume of solid waste to be disposed in landfills, it also lessens the dependency on fossil fuel and Greenhouse Gas (GHG) emissions.

The present study was conducted in three phases. In the first phase the assessment of waste generation in Kottayam municipality and its disposal practice followed in the dumpsite have been studied. Additionally, the impact of dump yard on the ground water of the surrounding areas was assessed. Next two phases of this study involve the feasibility of recovering energy and manure from OFMSW (organic fraction of municipal solid waste) and treatment of leachate arising from the dump yard. Energy recovery studies were conducted by operating anaerobic digesters with feedstock of OFMSW, while manure recovery studies were done using earthworms. Constructed wetland and nutrient film technique (NFT) experiments were conducted to treat the leachate.

2. Review of literature

Increase in human population results in consumption of more resources and generation of more waste. The waste generation in Kerala state is comparable with other states in the country. Rapid urbanization, constant change in consumption pattern and social behavior have caused massive waste generation in Kerala beyond the assimilative capacity of the environment and capacity of the existing waste management systems (Varma, 2006). For the

effective management of municipal solid waste in Allahabad, India Sharholy et al. (2007) determined the quantitative and qualitative characteristics of MSW along with basic information and created a GIS based information system for Allahabad city. The total quantity of MSW has been reported as 500 ton/day and the average generation rate of MSW has been estimated at 0.39 kg/capita/day.

Degradation and stabilization of waste in landfills has been observed to occur according to an ordered succession of physical, chemical and biological processes over time. These include an initial, short-lived aerobic degradation phase followed by three phases of anaerobic degradation: (I) acid-fermentation, (II) intermediate anaerobiosis, and (III) methanogenesis. Each stage represents a progression in the process and rate of decomposition of organic matter present in the wastes, and the resultant leachate produced can be identified by characteristics indicative of each stage (Jorstad *et al.,* 2004). The leachate may be characterized as a water based solution of four major groups of pollutants namely dissolved organic matter, inorganic macro-components (Ca, Mg, Na, K, Cl, etc.), heavy metals (Cd, Cr, Cu, Pb, Ni and Zn) and relatively low concentrations of xenobiotic organic compounds. Other compounds like B, As, Se, Ba, Li, Hg and Co are found but in very low concentrations and are only of secondary importance (Christensen *et al*., 1994). Depending upon the nature of these formations and in the absence of leachate collection system, leachate has reportedly been associated with the contamination of aquifers underlying landfills (El-Fadel *et al*., 1997).

Many studies have reported that activated carbon can be used an adsorbent for the removal of organic compounds and heavy metal ions from industrial effluents and leachate. Adsorption technique is a mass transfer process by which a substance is transferred from the liquid phase to the surface of a solid, and becomes bound by physical and / or chemical interactions. Several studies were conducted and published using activated carbon for leachate treatment (Martin and Ng, 1984; Morawe *et al*., 1995; Diamadopoulos, 1994; Wasay *et al*., 1999; Kargi and Pamukoglu, 2004).

In the last four decades, there have been considerable emphasis on the use of aquatic plants in pollution control. Phytoremediation is defined as ‘the

utilization of vascular plants, algae and fungi to control, breakdown or remove wastes, or to encourage degradation of contaminants in the rhizosphere or root region of the plant' (McCutcheon and Schnoor, 2003). Use of native plant species for phytoremediation is generally favoured; natives require less maintenance and present fewer environmental and human risks than do non-native or genetically altered species. Nutrient film technique (NFT), also known as Thin film technique (TFT) comprises of shallow trenches, filled with wastewater at a depth of 4 -5 inches in which the plants are grown hydroponically. "Constructed wetland" (CW) is defined as a wetland specifically constructed for the purpose of pollution control and wastewater treatment, at a location other than existing natural wetlands.

Yount (1964), Sheffield (1967), Boyd (1976), and Cornwell et al. (1977) were among the first scientists to demonstrate the removal potential of aquatic plants. Subsequently, many studies have been reported by Reddy and Smith (1987); Trivedy and Joag (1989). According to Wolverton (1987), the scientific basis for wastewater treatment in a vascular aquatic plant system is the co-operative growth of both the plant and microorganism associated with the plant rhizosphere.

Anaerobic digestion is a process used in many different technical applications for the treatment of organic solid waste for gas production and waste stabilization. According to Angelidaki et al. (2003) anaerobic degradation is the process of converting organic carbon by subsequent oxidations and reductions to its most oxidized state (CO_2), and its most reduced state (CH_4) in the absence of oxygen.

Vermicomposting is one of the approaches for mobilizing the organic fraction of municipal solid wastes for meeting crop nutritional needs and thus constitutes a productive waste management strategy (Sim and Wu, 2010). It has been demonstrated that earthworms can process household garbage, city refuse, sewage sludge and wastes from paper, wood and food industries (Hartenstein *et al.,* 1979; Senapati and Dash, 1982; Abbasi, 1999; Abbasi and Ramasamy, 2001).

3. Organization of Thesis

The thesis is divided into six chapters with different aspects like assessment of municipal solid waste (MSW) generation in Kottayam municipality, impact of MSW disposal on the groundwater of the dumpsite, studies on the treatment of hazardous landfill leachate using a few techniques, recovery of energy from OFMSW by anaerobic digestion technology and finally recovery of manure from OFMSW.

4. Chapter- I: Municipal solid waste generation, treatment and disposal – An overview

Chapter I gives a brief introduction about MSW and its major environmental impacts, composition of MSW and various treatment / processing techniques generally adopted have been highlighted.

5. Chapter- II: Assessment of MSW generation and disposal at Kottayam municipality using GIS

This chapter focuses on the studies related to the urbanization trend of Kottayam municipality in relation with the solid waste generation and management. Remote sensing (RS) and geographical information system (GIS) were used in studying the current solid waste management practice in Kottayam.

5.1. Salient findings

From the present study it is noted that due to rapid urbanization, the generation of solid waste would also increase and installation of suitable sanitary landfills may nullify the impacts of waste generation on the public health in particular and environment in general. Results from the ground water studies shows In contrast to general expectations the groundwater contamination was limited. The low permeability of the clay soil present in the study area may be serving fortunately as a barrier and prevent the *in situ* percolation of leachate, thus the groundwater contamination is limited.

6. Chapter- III: Landfill leachate treatment with adsorption and phytoremediation techniques

Chapter III is divide into two parts, part I deals with the treatment of landfill leachate by activated carbon adsorption (ACA) technique. Activated carbon used in the present study was derived from cashew nut shell. Part II demonstrates the efficiency of two native aquatic/semi aquatic plants (*Colocasia esculenta* and *Limnocharis flava*) for treating landfill leachate by nutrient film technique (NFT) and constructed wetland (CW) systems.

6.1. Salient findings

The removal of pollutants such as heavy metals and COD by the activated carbon obtained from cashew nut shells found comparable. The plants tested in this work showed good tolerance to experimental conditions. The performance of both *C. esculenta* and *L. flava* in the NFT and CW systems in terms of COD, CODs, BOD, nutrients and metal removal is encouraging and comparable with the reported values for other plants.

7. Chapter IV: Anaerobic digestion of OFMSW for the recovery of energy

This chapter deals with the recovery of energy from OFMSW in the form of biogas from different combinations of different types of anaerobic digesters. During anaerobic digestion the organic material was biologically converted to CH_4 and CO_2 with the action of different group of microorganisms present in the digester. In India the biogas plants are mainly single chamber reactors which affect the efficiency of the plant due to the presence of different kind of microbial communities in a single vessel, while different microbial communities may require different process regimes with varying environmental and nutritional requirements present inside. In the present study implementation of separate digesters with compartments and separate high-rate biomethanisers were used. Three types of digesters were used in this study viz: Type I (HSAD) having two compartments (upper solid phase and lower liquid phase) in a single vessel. Type II digester had two separate vessels one for acid phase and other one was a methaniser. Type III digester consisted of HSAD (Type I) clubbed with a separate methaniser, upflow anaerobic filter (UAF) and continuously stirred tank reactor (CSTR) were used as methaniser.

7.1. Salient findings

The overall findings of this study indicate the performance of the digesters increased along with the level of phase separation. Accordingly the Type I digesters with minimal phase separation performed least, while Type III digester with better phase separation performed better than other two types.

8. Chapter V: Recovery of manure from OFMSW by vermitechnology

The main objective of this chapter is to study the efficiency of two epigeic earthworms (*Eudrilus eugeniae* and *Eisenia foetida*) to convert the OFMSW into manure. The principle behind vermicomposting is that certain species of earthworms can consume organic residuals very rapidly and fragment them into much finer particles by passing through the gizzard, an organ that all earthworm posses. Earthworms derive their nourishment from microorganisms that grow upon the organic materials which were consumed and processed by the earthworms (Abbasi and Ramasamy, 2001).

8.1. Salient findings

The present study showed that OFMSW can be used as a suitable substrate for vermicomposting. Even the spent OFMSW from acid phase fermenters mixed with cow dung could be successfully precessed by both earthworms and produced vermicasts. The rate of increase in worm biomass and production of young ones in such OFMSW fed vermireactors suggest that OFMSW can be used as a substrate by both the species of earthworms and therefore the vermireactors could be operated sustainably with these substrates as feed.

9. Chapter VI: Summery and Conclusion

The present study made as assessment of municipal solid waste generation, its disposal in Kottayam municipality along with RS and GIS aided studies on urban sprawl, distribution of waste collection spots in different wards of Kottayam municipality. The study also made an attempt on some advanced technological options for the treatment of hazardous leachate generated from MSW dump yard and the techniques for the recovery of energy and manure from OFMSW.

The study reveled that urbanization has a direct impact on the MSW generation in Kottayam municipality. The impact of leachate generated in the dump yard of Kottayam municipality found to have little effect on local ground water. Ability of the weeds to decontaminate landfill leachate was found comparable with the similar studies done by other researchers. Biogas production from the OFMSW was found better in phase separated digesters coupled with high-rate methanisers. Vermicomposting of the OFMSW showed good results in terms of vermicast recovery from the vermireactors employed with epigeic earthworm species. In general, the study reveled that OFMSW which is compounding almost 70% of the MSW generated in the Kottayam municipality can be used as a good resource for the recovery of energy and manure by using high solid anaerobic digesters and vermireactors of suitable scale. Such attempts will reduce the volume of waste flow into the landfills which in turn will reduce the extra loading in the landfills, this will increase the life of the landfill.